Six Color Story of the Superheterodyne with AVC

LESSON ND-26

SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

PUEBLO, COLORADO

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This lesson in general deals with small radio parts as well as a complete color circuit showing these parts connected together. Thus throughout the book we have shown views of parts, meters and test equipment which are associated with circuits of this type.

This lesson is designed to bring together and correlate the principles you have studied in previous lessons on the superheterodyne and automatic volume control. Colors are used to bring out the highlights and to enable you to study the separate functions of the various circuits.

The block diagram in Fig. 1 indicates the general nature of the circuit to be discussed in this lesson. It is divided into five sections. The first section combines in one stage the functions of preselection, oscillation and 1st detection. The tube employed for this stage could be any of the converter types with a 6.3 volt filament. Typical examples are the 6A8, 6A7, 6A7S, 6SA7, 6K8, 6J8, 7A8, 6L7, etc. The second section in Fig. 1 employs an IF amplifier tube. Typical tubes are the 6K7, 7A7, 7H7, 6AB7, 6SK7, 6SS7, etc. The third section of Fig. 1 employs another combination tube of the diode-pentode type such as the 6B8, 6B7, 7E7, etc. The fourth section comprises the two stage amplifier. The single tube, or 1st audio stage, may employ such tubes as the 6C5, 6J5, 6P5, 7A4, 6L5, etc. The push-pull stage may employ such triode tubes as the 6A5-G, 6A3, 6B4, 6F6, etc. The speaker may be of the conventional dynamic type with suitable coupling to the output tubes. The rectifier may, in general, be of the type 80, 5T4, 5U4, 5X4, 5Z3, 5W4, 5Y3, 5Y4, etc. *All of the foregoing tube types are possibilities around which a circuit might be designed.* To have a definite set of characteristics to work with, the following tube types have been selected for the circuit of Fig. 2, which is shown in the center of this book. For V1, type 6A7; for V2, type 6K7; for V3, 6B7; for V4, 6C5; for V5 and V6, 6A5 and for V7, 5T4.

Before a given circuit can be

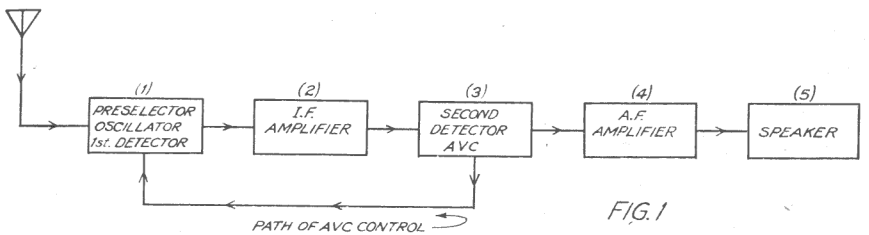
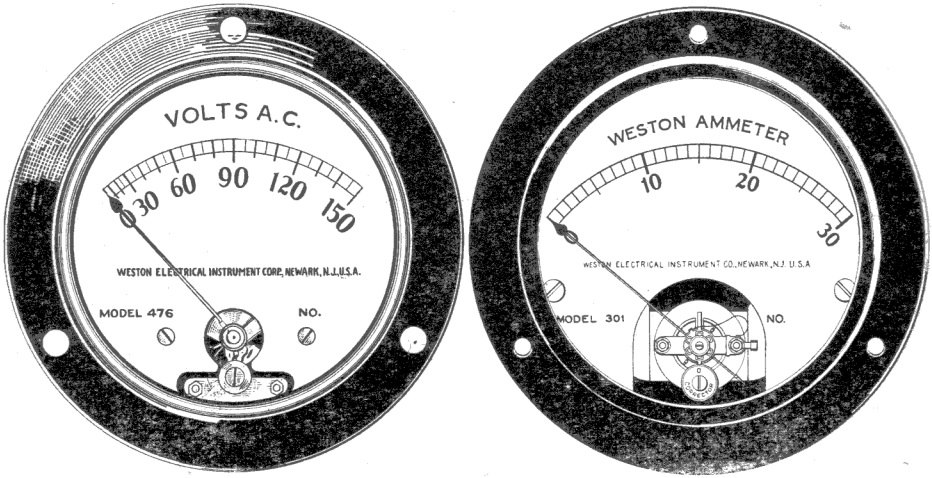


FIG. 1



The above shows two types of the popular Weston meters. The meter on the left is used for AC voltage measurements, having a range from 0 to 150 volts. The meter on the right is a Weston DC ammeter, having a range from 0 to 30 amperes.

designed around a set of tubes, it is first necessary to know the voltage at which the various tube elements will operate and the amount of current they will draw. Normal plate voltage for all of the tubes in Fig. 2 is about 250 volts. At this approximate voltage the 6A5 tubes will draw 60 milliamperes each for a *total* of 120 milliamperes. The 6C5 will draw .5 milliampere. This tube is used in a resistance coupled stage which accounts for its low plate current. The 6B7 will draw a plate current of 6 milliamperes and the screen will draw 1.5 for a total of 7.5 milliamperes for the entire tube. The 6K7 will draw 7 milliamperes for the plate and 1.7 for the screen grid for a total of 8.7 milliamperes. The 6A7 plate current is 3.5, screen current is 2.7 and the *anode grid* current 4, for a total of 10.2 milliamperes for the entire tube. Thus the total current demand for the tubes is 120+.5+7.5+10.2=146.9 or 147 milliamperes. To allow for a bleeder current of 15%, 22 milliamperes are allotted to R6 in Fig. 2 *for a total current drain of* 169 *milliamperes.* The maximum rated current load for the 5T4 rectifier may be up to 225 milliamperes so it will take care of the 169 milliampere load nicely. Actually, the current load will be less than 169 milliamperes because the net plate voltage on some of the tubes *will be less than rated values* which will result in a decreased current drain. This will be explained later.

The logical place to begin with the description of circuit design is at the rectifier output. Previous lessons have shown how almost any value of output voltage (within limits of the circuit) may be obtained at the output of a rectifier by arranging circuit values properly. So in Fig. 2, it may be assumed that sufficient DC is available across the cathode (filament, in this case) and center tap to the high voltage winding. Only one choke coil, L_{14} (the speaker field winding), is used in the filter

circuit. This follows present-day design practice. It may be rated at about 700 ohms and will have an inductance of about 20 henries. With a current flow through it of 169 milliamperes, the voltage drop across it will be 700×.169 or 118.3 volts. With 250 volts required at the filter output, the DC output across the cathode of the rectifier and the center tap to the high voltage winding should be 250+118.3 or 368.3 volts. The characteristic curves for the 5T4 rectifier tube show that for an approximate DC output of 370 volts, at 169 milliamperes, with an 8 mfd. filter condenser and L at 20 henries, the AC input per plate, of the rectifier tube should be approximately 375 volts. Thus, the high voltage winding for transformer T2 in Fig. 2 should be rated at 375 volts each side of the center tap for a total AC plate to plate voltage of 750 volts. For the 5T4 rectifier filament winding on T2 the rating is 5 volts at 2 amperes. The filament low voltage winding on T2 should be rated at 6.3 volts and 3.7 amperes. This allows .3 ampere each for V1, V2, V3 and V4. For V5 and V6 the current rating is 1.25 ampere for each tube. Thus, in Fig. 2, all power unit values have been given. Condensers C_{28} and C_{29} have a capacity of 8 mfd. They are of the electrolytic type and are rated at 600 volts DC. The voltage divider is scattered throughout the receiver wiring and held in place by it.

A better understand of the entire DC network can be had by referring to Fig. 3 which shows it in simplified form. It is suggested that you study the following in careful detail for it involves fundamental principles you will be called upon to use often. In Fig. 3, the B+ and B− points correspond to the output of the power unit filter in Fig. 2. From an examination of this figure it will be seen that the DC current divides into six parallel paths as denoted by the numerals in the circles. The first path from left to right in Fig. 3 represents the push-pull stage for tubes V5 and V6. The primary of the output transformer is symbolized by P1 and P2. The internal plate resistance (RP) of the two tubes is symbolized by RpV5 and RpV6. The currents of both tubes flow through R_{15}, the

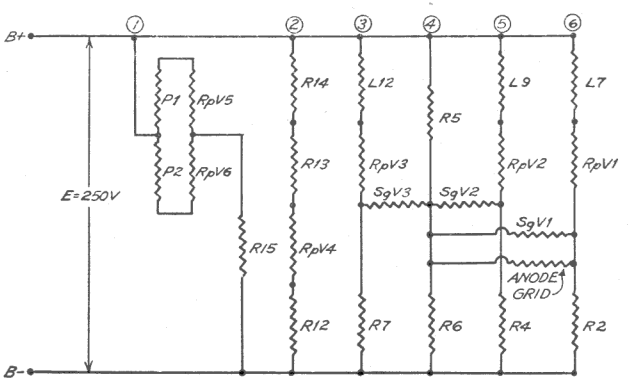
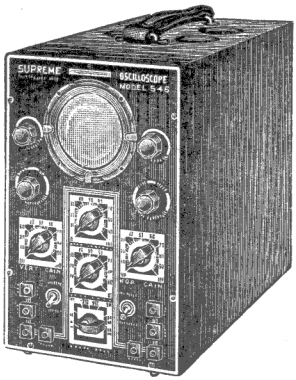
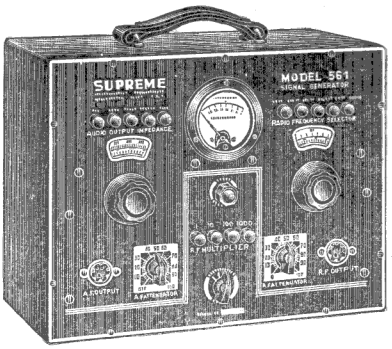


FIG. 3

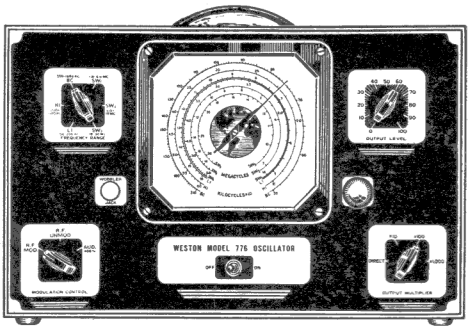




Above are shown two types of Supreme test equipment. The instrument on the left is an oscilloscope or oscillograph employing a three inch cathode-ray tube. It is used in adjusting tuned circuits and for other test purposes as you will learn later on in other lessons. The instrument on the right is a signal generator of the all-wave type—it being used to provide a test signal in several frequency bands. It includes its own output meter.

bias resistor. *Note this is self-bias.* The second parallel path consists of R_{14}, R_{13}, RpV4 and R_{12} which is the bias resistor for tube V4. The third parallel path is though L_{12}, RpV3 and R_7. The fourth path is through R_5 and R_6. This branch is further subdivided because of the screen grid of tube V3 and symbolized in Fig. 3 as SgV3; the screen grid of V2, SgV2; the screen grid of V1, SgV1; and the anode grid (No. 2 grid of the 6A7) of tube V1. Thus, at the junction of R_5 and R_6 current divides into six circuits. Assuming current flow from negative to positive, all of the bleeder current of the fourth parallel branch in Fig. 3 will flow through (1) R_6. There are five other paths represented by (2) anode grid of V1, (3) screen grid of V1, (4) screen grid of V2, (5) screen grid of V3 and (6) through R_5 to B+. The fifth main parallel path in Fig. 3 is through L_9, RpV2 and R_4. The sixth and final path is through L_7, RpV1 and R_2.

If each of the six main parallel paths in Fig. 3 are symbolized by a separate resistor consuming a certain amount of power, *the circuit they present* to the output of the power unit in Fig. 2 will appear as in Fig. 4. Thus, the circuit of Ra in Fig. 4 may be made to represent circuit (1) in Fig. 3 consisting of P1 and P2 in parallel, RpV5 and RpV6 in parallel and these four in series with R_{15}. In this way the *load* of a given circuit can be reduced to its simplest form which helps to get an overall picture of the basic load on a power unit circuit such as the one shown in Fig. 2. To do this, of course, the voltage E across the load must be known as well as the current through it. These values



This view shows another popular Weston test instrument. It is a signal generator or test oscillator and covers several frequency bands so that all-wave circuits may be adjusted.

may be found by measurement or by calculation. For example, in Fig. 3 it is known that the voltage available across the output of the filter in Fig. 2 is 250 volts DC with a predetermined current load of .169 ampere. Also, from examination of branch circuit 1 in Fig. 3, it may be assumed that this part of the circuit is going to consume a part of the .169 ampere load. To find how much current will flow through branch circuit 1 of Fig. 3, it is only necessary to refer to a characteristic table for the 6A5 tube. With approximately 250 volts on the plate and 45 volts negative on the grid, there will be a plate current of 60 milliamperes. This requires that there be 295 volts to operate the 6A5 tube (250 for the plate and 45 for the grid) whereas only 250 volts are available. Further reference to the characteristic curves for the 6A5 shows that with a plate voltage of approximately 220 volts, a plate current of 60 milliamperes can still be obtained if the grid bias is reduced to 30 volts negative. Thus, if 30 volts are allotted for the grids of the two tubes it will leave 250 −30 or 220 volts for the plates of the tubes. This means the AF grid swing for the 6A5 tubes must be limited to less than 30 volts, and it also means the maximum undistorted power output will be less because the plate voltage is less. However the output of a circuit, like Fig. 2, would be more than sufficient for ordinary room volume even if the plates are worked at a reduced voltage. For the entire push-pull stage, two tubes are required and, therefore, the total current through R15 in Fig. 3 will be 120 milliamperes. If the required grid voltage for the 6A5 tubes is 30 volts, R_{15} will equal $\frac{30}{.12}$ or 250 ohms, and its power rating will equal $.12 \times 30$ or 3.6 watts. Now it is clear that 60 milliamperes must flow through RpV6 and P2 and that a like amount must flow through RpV5 and P1 of Fig. 3. A normal value for the primary winding for the output transformer consisting of P1 and P2 would be 250 ohms (DC) for each half winding. If .06 ampere flows through P1 and P2 the voltage drop across them will equal $.06 \times 250$ or 15 volts. This subtracted from 220 volts leaves 205 volts across RpV5 and RpV6. The no signal power dissipated in RpV5 and RpV6 is equal to $.06 \times 205$ or 12.3 watts. Across P1 or P2 the power is equal to $.06 \times 15$ or .9 watt. There are two tubes so P1 and P2 equal 1.8 watts, RpV5 and RpV6 equal 24.6 watts and R_{15} equal 3.6 watts. For the entire No. 1 circuit in Fig. 3, the total power is $1.8+24.6+3.6$ or 30 watts. Thus, Ra in Fig. 4 may be symbolized as a 30 watt resistor. Furthermore, it is known that 120 milliamperes flow through it. Therefore, its effective *symbolic value* is equal to $\frac{30}{.12^2} = \frac{30}{.0144}$ or 2,083 ohms. In the same general way, symbolic values could be obtained for Rb, Rc, Rd, Re and Rf in Fig. 4. In

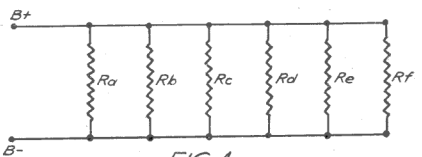
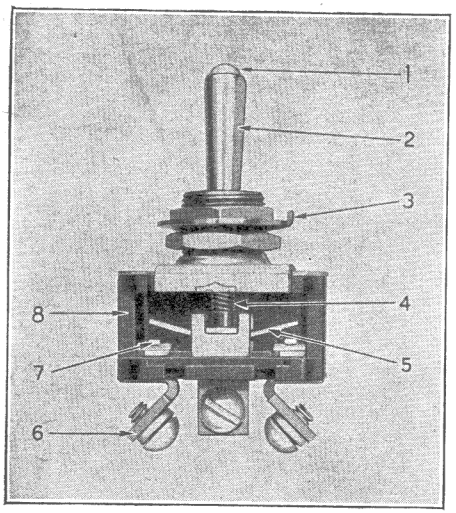


FIG. 4

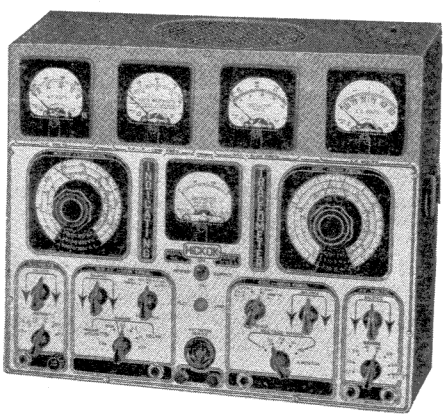


Many types of switches are used in radio circuits. Their design largely depends upon their application and the amount of current they must carry. Shown above is a Cutler-Hammer switch of special construction rated at 24 amperes and 24 volts. It is used in low voltage circuits where a high value of current must be carried.

this way, the total load on a given rectifier tube may be simplified. Radio men often reduce a circuit to these simple considerations in order to get a simplified picture of what is taking place in the entire circuit.

Now referring back to Fig. 2, in the process of showing the entire load on the power unit, values were obtained for the plate, grid and cathode circuits of the push-pull stage. Tube V4 is next. In its plate and cathode circuit are included R_{14}, R_{13} and R_{12}. R_{14} is principally a filter resistor and its value need not be over 10,000 ohms. This is a 6C5 tube working in a resistance coupled stage. Its recommended plate load resistor R_{13} should be 100,000 ohms. The recommended value of R_{12} (cathode resistor) is 5,300 ohms. With this as a total load on the tube, the current through it will be .0005 ampere with a corresponding grid voltage of 2.65 volts. Thus, across R_{14} the voltage drop will be equal to $10{,}000 \times .0005$ or 5 volts. Across R_{13}, it will be $100{,}000 \times .0005$ or 50 volts. Across R_{12}, it will be $5300 \times .0005$ or 2.65 volts. This totals $5+50+2.65$ or 57.65 volts, leaving $250-57.65$ or 192.35 volts to operate tube V4. Since the voltage across the tube is 192.35 volts and the *no signal current* through it is .0005 ampere, the DC resistance of the tube is equal to $\frac{192.35}{.0005}$ or 384,700 ohms. Thus, the effective *symbolic load of Rb* in Fig. 4 may be represented as a resistance equal to (R_{14}) 10,000 + (R_{13}) 100,000 + (RpV4) 384,700 + (R_{12}) 5300 or 500,000 ohms. Its power rating will be equal to I^2R or $.0005^2 \times 500{,}000$ or .125 watt.

The next tube, V3, in the circuit of Fig. 2 is the 6B7. Its plate current is equal to 6 milliamperes. The DC resistance of coil L_{12} is 50 ohms so the voltage drop across it is equal to $50 \times .006$ or .03 volt. The



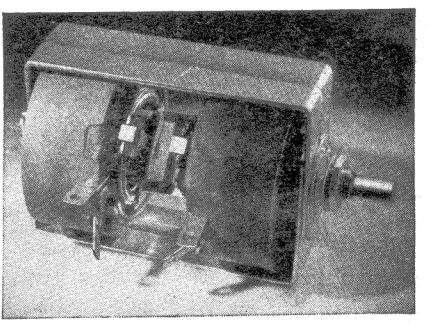
This view shows another versatile piece of test equipment. It is a Traceometer made by Hickok and is similar to other types of instruments known as a Channalyst or Signal Tracer.

current through R_7 (cathode resistor of the 6B7) is equal to the plate current (.006) plus the screen grid current (.0015) for a total of 7.5 milliamperes. The required control grid voltage for the pentode grid of the 6B7 is 3 volts. So the value of R_7 is equal to $\frac{3}{.0075}$ or 400 ohms. The voltage distribution across circuit 3 in Fig. 3 is L_{12}, .3 volt; RpV3, 246.7 volts and across R_7, 3 volts. With 246.7 volts across RpV3, the DC resistance of the tube is equal to $\frac{246.7}{.006}$ or 41,116 ohms. The total resistance of circuit 3, is 50+41,116+400 or 41,566 ohms. It may be symbolized as Rc in Fig. 4 as a 41,566 ohm resistor rated at 1.52 watts.

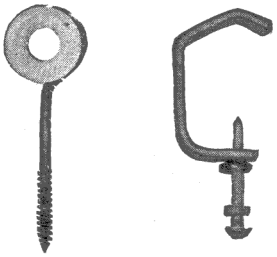
Tube V2 in Fig. 2 is next. The resistance of coil L_9 is 50 ohms with a current of 7 milliamperes through it giving a voltage drop of 50×.007 or .35 volts. This tube has a screen current of 1.7 milliamperes for a total of 8.7 milliamperes to flow through R_4. The control grid of tube V2 requires 3 volts so R_4 is equal to $\frac{3}{.0087}$ or 344 ohms. With 3 volts across R_4 and .35 volts across L_9, the voltage across tube V2 is equal to 250−3.25 or 246.65 volts. Thus, RpV2 in Fig. 3 is equal to $\frac{246.65}{.007}$ or 35,235 ohms. Thus, Rc in Fig. 4 may be symbolized as a resistor equal to 50+35,235+344 or 35,629 ohms rated at 1.72 watts.

The final tube V1 in Fig. 2 has a plate current of 3.5 milliamperes. With L_7 rated at 50 ohms, the voltage drop across it will be equal to .175 volt. The current through R_2 is 3.5 for the plate, 2.7 for the screen and 4 for the anode grid for a total of 10.2 milliamperes. The control grid voltage for tube V1 is 3 volts so R_2 is equal to $\frac{3}{.0102}$ or 294 ohms. With .175 volt cross L_7 and 3 volts across R_2, the voltage across RpV1 in Fig. 3 is equal to 250−3.175 or 246.825 volts. Thus, RpV1 is equal to $\frac{246.825}{.0035}$ or 70,521 ohms. The total resistance, therefore, for the entire plate circuit is 50+70,521+294 or 70,865 ohms and may be symbolized in Fig. 4 as R_F rated at .8912 watt.

The No. 4 circuit (R4 and R6) in Fig. 3 may be treated separately or it could be included along with the other circuits. It is treated separately here because it simplifies the calculations. The main circuit consists of R_5 and R_6. However, at the junction of R_5 and R_6 there are four more branch circuits consisting of SgV3, SgV2, SgV1 and the anode grid for V1 in



In today's applications, many types of volume controls, impedance matching devices and other forms of variable resistances must be used. This view shows an enclosed, two-unit type of control as made by Clarostat. Such units are made in many different designs according to specifications given to the manufacturer.



This view shows two important, but not very often used, antenna accessories. The unit on the left is an "I" type antenna lead-in insulator used to prevent the lead-in wire from rubbing against walls and other objects. The unit on the right is a ground clamp, permitting good electrical contact to be made to a water pipe so as to form a good ground connection.

Fig. 2. The static or no signal resistance of each of these circuits may be found as follows:

$$\text{SgV3} = \frac{100}{.0015} = 66{,}666 \text{ ohms}$$

$$\text{SgV2} = \frac{100}{.0017} = 58{,}823 \text{ ohms}$$

$$\text{SgV1} = \frac{100}{.0027} = 37{,}037 \text{ ohms}$$

$$\text{Anode} = \frac{100}{.004} = 25{,}000 \text{ ohms}$$

The electrical equivalent of tubes V1, V2 and V3 is shown in Fig. 5. Study this figure carefully and note the internal screen grid resistance of each tube is in series with R_5 and these two together are in parallel with the Rp of each tube. In addition, the cathode bias resistor of each tube is in series with this branch circuit. An effective circuit is shown in Fig. 6 for V3 showing how SgV3 fits into the complete tube circuit. You may make the following similar calculations for the other tubes in Fig. 3 and, in the case of tube V1, allow one more branch circuit for the anode grid. It has been previously shown that RpV3 equals 41,116 ohms, SgV3 equals 66,666 ohms and R_7 equals 400 ohms. The current through R_6 is equal to 1.5+

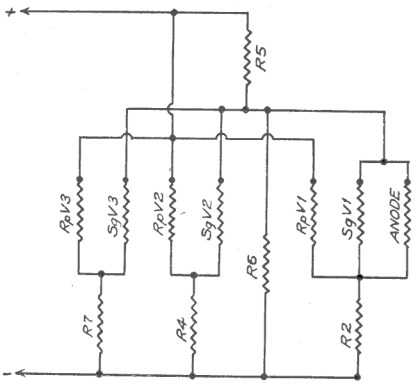


FIG. 5

1.7+2.7+4 for the screen grids and anode grid of V1. This totals 9.9 plus 22 (for the bleeder R_6) or 31.9 milliamperes. The rated screen grid voltage is 100 volts so R_5 must reduce the voltage 250−100 or 150 volts. Thus R_5 is equal to $\frac{150}{.0319}$ or 4,702 ohms. This leaves the value of R_6 to be determined. With 100 volts across it and with a current through it of 22 milliamperes, its value is equal to $\frac{100}{.022}$ or 4,545 ohms. This completes the determination of the various voltage divider resistor values in the main circuit of Fig. 2.

Next refer to Fig. 6 and note how the screen grid (SgV3) resistance may be shown in series

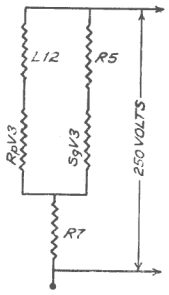


FIG. 6

with R_5 and in parallel with RpV3. It should be understood that R_5 also carries the bleeder, screen and anode current of the other tubes, but this need not be considered in Fig. 6. Since the screen grid (SgV3) draws .0015 ampere R_5 in Fig. 6 can be considered a symbolic resistance equal to 97,800 ohms. This is true because only 246.7 volts is across R_5+SgV3. If the screen grid current is .0015 ampere with SgV3 equal to 66,666 ohms, then R_5 must effectively equal 97,800 ohms because the total resistance required to limit .0015 ampere with a voltage of 246.7 is 164,466. Thus 164,466 minus 66,666 equals 97,800 for the *effective* value of R_5 in Fig. 6. The *effective resistance value* for the entire circuit of Fig. 6 is, therefore, equal to:

$$\frac{(L12+RpV3)\times(R_5+SgV3)}{L12+RpV3+R_5+SgV3}+R_7$$

$$\frac{(50+41{,}116)\times(97{,}800+66{,}666)}{50+41{,}116+97{,}800+66{,}666}+400$$

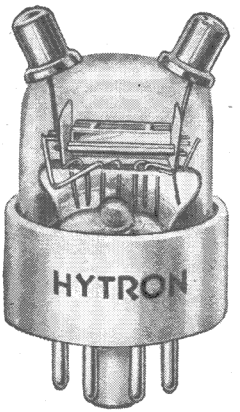
$$=\frac{41{,}166\times164{,}466}{205{,}632}+400$$

$$=\frac{6{,}770{,}407{,}356}{205{,}632}+400$$

$$=32{,}924+400$$

$$=33{,}324 \text{ ohms.}$$

In a previous calculation it was shown that the effective value of circuit 3 in Fig. 3 was 41,566 ohms rated at 1.52 watts. This included the screen grid current through R_7 but it did not include the resistance effect of the screen grid and R_5. If these are included the circuit of Fig. 6 results, and this time the effective resistance is equal to 33,324 ohms. Thus it may be symbolized at this value as Re in Fig. 4 rated at 1.87 watts. If, for some



The above Hytron tube is their type HY615. It is a war-time development used extensively by the armed forces on ultra-high frequencies. This particular tube is of the transmitting type but is representative of the small type of tube for high frequencies used in both transmitters and receivers.

reason, you wanted a similar value for circuits 4, 5 and 6 of Fig. 3 they may be treated as for Fig. 6. Then to get the effect of R_5 and R_6 alone, they could be treated as a separate circuit through which flows 22 milliamperes of current with an impressed voltage of 250 volts. In this case R_6 would have its assigned value of 4,545 ohms. However, a *new effective value* would have to be found for R_5 because, in this case, only the bleeder current of R_5 is assumed to flow through it. Normally, .0319 ampere flows through R_5, but .0319−.022 or .0099 is allotted for the screen and anode grids and will have been already included in the other branch circuits. The resistance required to limit .022 ampere with 250 volts is equal to $\frac{250}{.022}$ or 11,363 ohms. R_6 already has a value of 4,545 ohms so the new effective value of R_5 is equal to 11,363−4,545 or 6,818 ohms.

All of the foregoing shows just two methods of finding a solution

	Ohms	Current	Power in Watts	Voltage
R_{15}=	250	120	3.6	30
R_{14}=	10,000	.5	.0025	5
R_{13}=	100,000	.5	.025	50
R_{12}=	5,300	.5	.001325	2.65
R_7 =	400	7.5	.0225	3
R_6 =	4,545	22	2.2	100
R_5 =	4,702	31.9	4.785	150
R_4 =	344	8.7	.0261	3
R_2 =	294	10.2	.0306	3

to a given problem. Often an engineer, designer or serviceman will have problems of this nature, and he may have to use two or more such approaches to a given problem to find a satisfactory solution. Thus, it is imporant for you to thoroughly understand the foregoing principles. The calculation of voltage divider resist ances in a power unit, amplifier or receiver must be done precisely if good results are to be obtained. As a result of the foregoing calculations, the values of R_{14}, R_{13}, R_{12}, R_7, R_6, R_5 and R_2 of Fig. 2 have been determined. These are the only resistors in the circuit which have to do with the distribution of the DC voltage. Their corresponding values are given in the table at the top of this page.

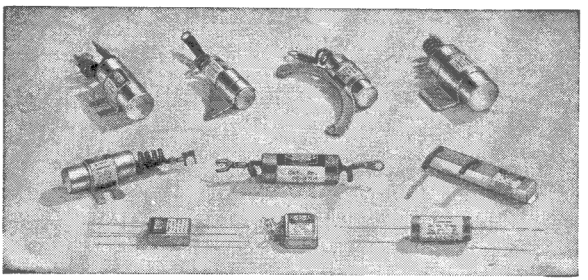
THE SIGNAL CIRCUITS

Now that you understand how the DC voltages are distributed in Fig. 2 you are ready to take up the study of the signal circuits. First refer to Fig. 2 and note the color arrangement. The color blocks at the top of the diagram give the key to the circuit. The first three blocks are green and represent the signal voltage distribution. Thus, green indicates RF, IF and AF signal voltages. The next color block is black and represents the chassis or point of zero potential. Black also indicates non-functional parts such as transformer iron cores, symbols, lettering, etc. The blue color block indicates the AVC circuit — that is parts below ground potential or more negative than ground. The yellow color block indicates parts and circuits just above ground potential—that is from zero on up to about 50 volts positive. The red color block indicates parts and circuits at a high DC potential such as plate and screen grid circuits. The final color block is brown and indicates raw AC 60 cycle circuits. All of these various functions will be explained in detail further on in this lesson.

You should understand that the circuit of Fig. 2 is purely a theoretical circuit and does not represent any particular receiver. All it is supposed to do is to illustrate the basic principles you have covered in the last few lessons.

THE GREEN CIRCUIT

From the study of other lessons you are, no doubt, now familiar with the way the signal is collected by the antenna and fed to the cou-



All forms of mobile radio apparatus must be well filtered to prevent ignition and motor interference. For this work special forms of condensers have been developed. The above view shows several condenseds of this type made by Cornell-Dubilier. **The odd-shaped metal pieces on these condensers are for mounting purposes.**

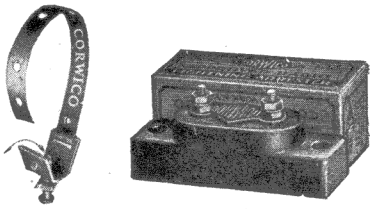
pling system to the input of the receiver. If you will examine the antenna circuit of Fig. 2 carefully, you will find a fine row of green dots. This represents the RF signal, and you will note it is fed by inductive coupling from L_1 to L_2. In the L_2-L_3, C_1-C_2 circuit, the signal voltage is tuned to resonance, and, in addition, a certain amount of selectivity is provided. The selected signal is then applied to the next resonant circuit associated with L_4. The transfer of signal energy from the selective circuit of L_2-L_3 and C_1-C_2 to the next resonant circuit is accomplished by a combination of inductance and *apparent capacity coupling* in the form of L_3. The small green dots grouped about L_1, L_2, L_3 and L_4 shows the distribution of the RF signal voltage at any one instant.

After the signal reaches the resonant circuit of L_4, C_3, C_4 and C_5 additional selectivity is gained. Thus, a signal to which has been applied a fair degree of selectivity is supplied to the control grid of tube V1 because it has been acted upon by two selective circuits. Therefore, that part of the signal circuit which has been described up to now may be called the RF or *preselector* section of the superheterodyne.

In some types of superheterodyne circuits, the pre-selector section may feed into a *separate RF amplifier tube.* The output of this tube may then feed into the input of a first detector or mixer tube. This tube, too, would also receive the oscillator energy so that a beat note frequency might be formed. All of this, you will remember, was covered in previous lessons.

You will also remember that you studied how a combination tube could be used to combine all of these functions within one tube. That is just what is done in Fig. 2. Tube V1 combines the functions of RF amplification (only a slight amount of gain is usually obtained from a circuit of this type), and the function of first detector or mixer as well as operating as an oscillator.

Before going further, review for a moment what is taking place in the oscillator tuned circuit. This consists of C_8, C_9, C_{10}, L_6 and L_5. You will remember that this circuit is continuously oscillating at a certain frequency, the value of which is determined by the IF of



Here are two more important antenna accessories. The unit on the left is a ground clamp of the strap type. Holes spaced along the strap permit adjusting this unit to different sizes of water pipes. The unit on the right is a lightning arrestor, one side of it being connected to the antenna lead-in while the other side is usually grounded. These two units are made by the Cornish Wire Company.

the receiver. The distribution of green dots around the oscillator tuned circuit shows the oscillator energy is fed to No. 1 and No. 2 grids of the pentagrid converter tube. The blue grid or the one next to the cathode is called the input or No. 1 grid. The other grid next to it (No. 2) or the red one is called the output or anode grid because it has a high positive voltage applied to it. This grid is often referred to as the No. 2 grid in tube charts. In reality, the No. 2 grid functions *practically the same as a plate*—hence the name anode grid.

The oscillator energy variations built up between grids 1 and 2 may be considered as an AC source of energy which varies the flow of electrons between the plate and cathode of the tube. *This is one source of plate current variation.*

The second source of plate current variation is the aforementioned received RF signal energy which is also acting on the tube between the control grid (No. 4) and cathode.

Thus, there are two sources of AC energy varying the plate current of the tube. You will remember from your study of previous lessons that these may be thought of as being AC sources of energy in series with the plate current of the tube. You will also remember that, as a result of this action, *a beat or heterodyne frequency* is formed in the plate circuit of the tube.

This *new frequency*—the result of combining the received signal and the local oscillator energy—is called the IF or intermediate frequency. It appears across the tuned circuit of C_{13} and L_7 in Fig. 2 which is resonant to the IF frequency.

The signal is now transferred to the tuned circuit of L_8-C_{14}, which is also resonant to the IF. Thus, additional selectivity is now gained at the IF. This and the next IF transformer are designed to ideally match the output and input impedances of the tubes they couple. They are also designed to afford an exceptionally high degree of selectivity. Actually, their constants are so adjusted that they will adequately pass a 10 KC band of frequencies. An exceptionally sharp cut-off is provided on each side of this 10 KC band which accounts for the high degree of selectivity.

The signal is now applied to the grid of the IF tube, V2. Notice the grouping of the green dots up to this point. Note that they are quite heavy in the circuit of L_7-C_{13}, but not quite so heavy in the circuit of L_8-C_{14}. This denotes that selectivity has been gained between L_7 and L_8 at a *loss of signal strength.* However, this is all right as the amplification of tube V3 more than makes up for any

Here is shown another Supreme test instrument. It is called a Vedolyzer Model 560. It includes a three inch cathode-ray tube and is a form of Signal Tracer or Channalyst. It includes several special features especially designed to enable the service man to make a quality test in radio sets.

loss of signal strength in L_7C_{13}-L_8C_{14}.

After being applied to the control grid of tube V3, the signal now appears in the plate circuit of the same tube but in greatly amplified form. The grouping of green dots in the plate circuit of tube V3 shows in a relative way the growth in strength of the signal. It is now highly amplified and due to the selective nature of the various tuned circuits through which it has passed it has been isolated from interfering and unwanted signals. This signal now appears in the plate circuit of V3 and in the resonant circuit L_{12} and C_{21} from where it is transferred by inductive coupling to another resonant circuit L_{11} and C_{20}. This last circuit, you will note, supplies the IF to the diode plates and cathode through C_{22}. Thus, the IF is present for rectification in this diode section of the multi-purpose tube V3. Due to the rectification, a varying DC is produced and will be proportionately distributed across resistors R_{10}, R_8 and R_7 according to their resistance values. R_{10} and condensers C_{22} and C_{23} form a filter to prevent the IF from flowing through the volume control resistance R_8. A path of reactance is afforded the IF through C_{22} and C_{23} to the cathode. This filter, however, allows the AF to pass with very little opposition and as the resistance of the volume control R_8 is larger than that of R_{10} the largest value of AF voltage will be available across R_8. If you will examine the plate circuit of V3 closely you will find green dots where the IF is present and green dashes where AF exists. The DC voltage variations are taken from the junction of R_8 and R_{10} and supplied to the first three tubes as an AVC control grid voltage through the AVC filter network comprising R_9, C_{16}, R_1 and C_3.

From the movable contact arm of the volume control R_8, the AF is supplied to the grid of V_4. This tube is the first AF tube. Condenser C_{24} is a coupling condenser and serves to isolate the grid of V4 from the diode circuit, and, at the same time, allows the AF to reach the grid of V4. Resistor R_{11} is the grid leak or load resistor for V4.

Tube V4 amplifies the AF signal, and this amplified signal appears across the plate load resistor R_{13} with R_{14} acting as a filter resistor in connection with condenser C_{27}.

The center tap of the AF choke L_{13} is held at ground potential through the direct ground connection as indicated by the black circuit. Note this is the same arrangement as an input push-pull transformer with the primary omitted. Magnetic variations are set up in the entire winding of L_{13}

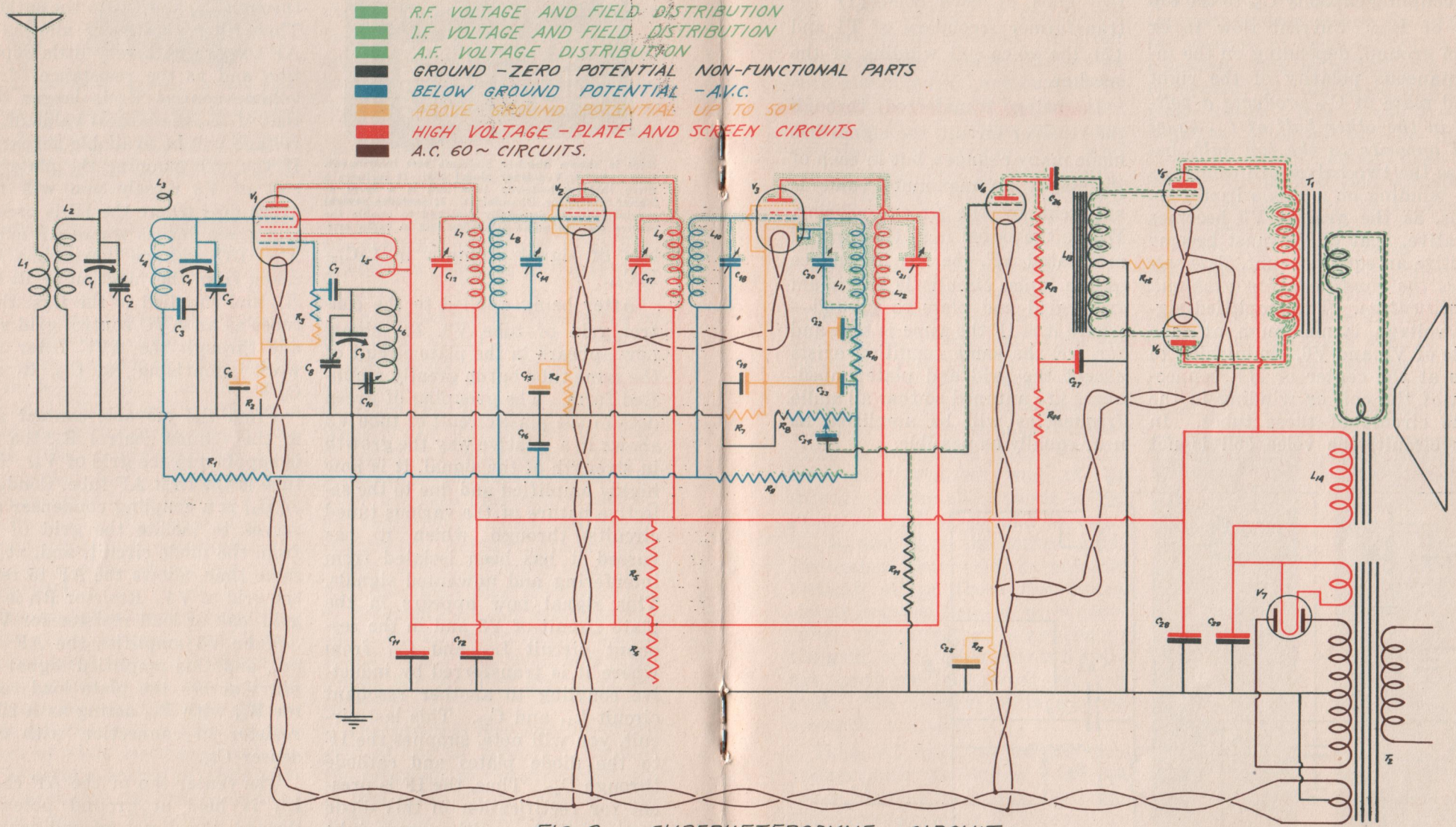

R.F. VOLTAGE AND FIELD DISTRIBUTION
I.F. VOLTAGE AND FIELD DISTRIBUTION
A.F. VOLTAGE DISTRIBUTION
GROUND - ZERO POTENTIAL NON-FUNCTIONAL PARTS
BELOW GROUND POTENTIAL - A.V.C.
ABOVE GROUND POTENTIAL UP TO 50V
HIGH VOLTAGE - PLATE AND SCREEN CIRCUITS
A.C. 60~ CIRCUITS.

FIG. 2. SUPERHETERODYNE CIRCUIT

as a result of being fed by C_{26}. In other words, the AF signal voltage from the plate of V4 is fed through the coupling capacity C_{26} to the top end of L_{13}. Current flow to or from ground, depending on the instantaneous polarity of the right hand plate of C_{26} *produces a voltage in the other half of* L_{13} *equal and opposite to the top half*, because the two halves are wound as one winding on a single iron core. Thus, as the grid of V5 becomes negative, that of V6 must become positive an equal amount. *This satisfies the conditions for push-pull amplification.* The amplified signal voltage is maximum at each plate of V5 and V6, diminishing to zero at the center or B+ connection of the coil or winding in the plate circuit of these tubes. In this circuit, the voice coil is not grounded, and the voltage of the signal fed to this circuit is uniformly distributed between the two ends of each coil—(1) the transformer secondary of T1 and (2) the voice coil winding of the speaker.

In being transferred through the receiver circuit, the signal has made many changes, but in each of its stages its maximum value is apparent by the green coloring. Where the signal is in the form of modulated RF, the AC impedance of the tuned circuits is maximum from grid and plate to ground—where it is IF the same is true and for AF the same condition exists except the grid and plate impedances are untuned so that all audio frequencies will be amplified as near equally as possible.

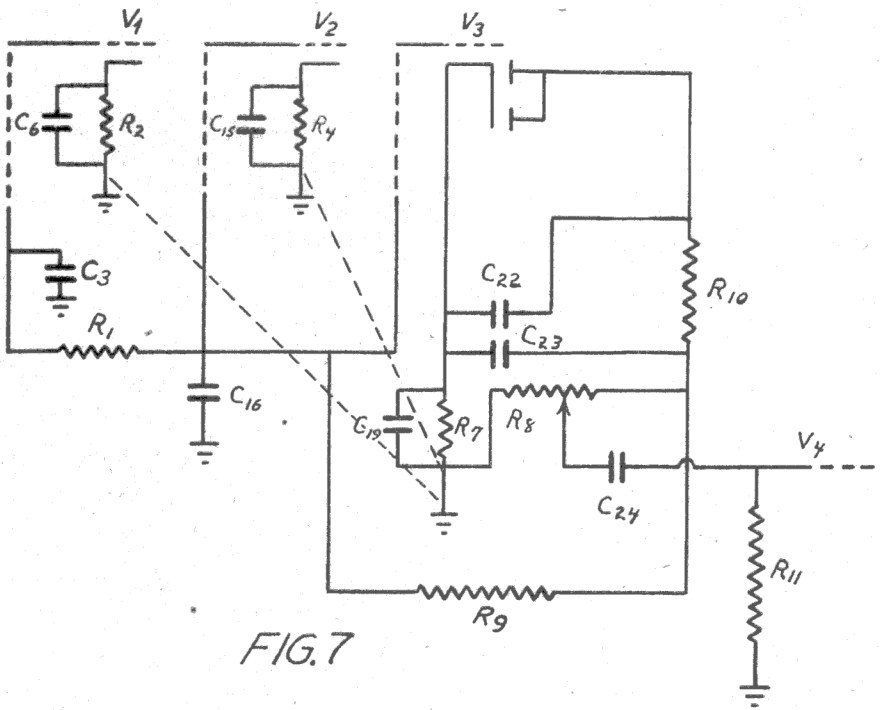


FIG. 7

THE BLUE AUTOMATIC VOLUME CONTROL CIRCUIT

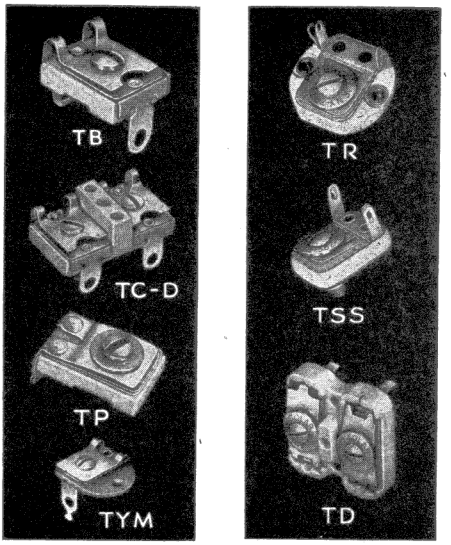
The blue circuit shows how the AVC voltage is distributed throughout the received. In order that you may follow this action with ease, the AVC and part of the AF circuit of Fig. 2 has been redrawn in Fig. 7. This figure does not show the various coils and tuning condensers to avoid confusion. However, the electrical path of the AVC voltage is shown, and you may consider that the various coils are, in effect, present.

First, consider how each of the tubes get their normal negative bias voltage—meaning, when no signal is received. In this case, tube V1 will get its bias voltage from the voltage drop across R_2. The path of this voltage (as denoted by the dotted lines) will be from the grounded end of R_2 through the metallic chassis to the grounded end of R_8 and through R_8, R_9 and R_1 to the control grid. Remember that this is possible through all of these resistances simply because there is *no current flow*—only a voltage is applied to the grid, or, in other words a voltage pressure is exerted on the grid. The normal voltage drop across R_2 is 3 volts.

Tube V2 gets its normal bias voltage (see the dotted lines between R_4 and R_7 in Fig. 7) from the grounded end of R_4 through R_8 and R_9 to the control grid of tube V2. Tube V3 gets its normal bias voltage from the voltage drop occurring across R_7. The path of this voltage is from the grounded end of R_7 to R_8 through R_9 to the control grid of tube V3.

Note in Figs. 2 and 7 that the diode plates of tube V3 have the same negative potential as the control grid of the same tube, due to the voltage drop across R_7. Thus, *the element of delayed AVC is introduced*—this principle, you will remember, was discussed in a previous lesson. Due to the 3 volts negative potential on the diode plates, the AVC action does not start until the rectified voltage in the diode builds up to a greater value than 3 volts.

When the signal builds up in value above 3 volts, it overcomes the initial 3 volt bias on the diode plates, and a negative voltage drop appears at the lower end of R_{10}. This voltage drop adds to the already minimum bias voltage on tubes V1, V2 and V3 so that these



Here are shown several types of trimmer condensers as used in all types of radio sets. Such condensers may also be referred to as padder condensers or compensating condensers. Both double and single unit types are shown. These are sometimes mounted on gang condensers or they may be mounted directly on RF or IF transformers. Often such units are also mounted separately on the receiving chassis. The letters appearing near each condenser are manufacturer's identification letters. Courtesy of Solar.

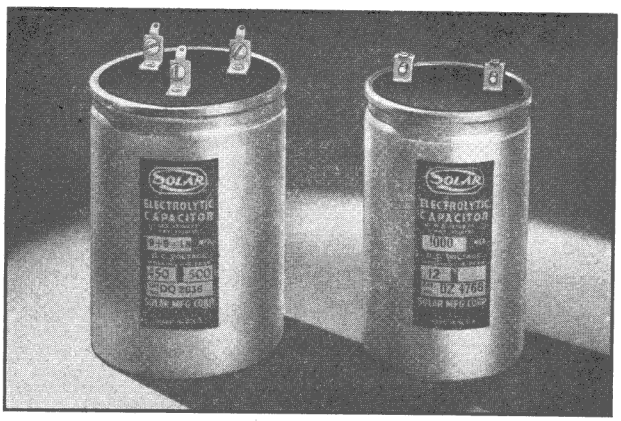
grids are made more negative. In this way, an automatic control of volume is obtained. Remember that the path of both the minimum bias voltage of 3 volts and that of the AVC voltage is through R_9 to the control grids.

Although the audio signal as well as the DC is impressed across R_9, it reduces along the length of the resistor until it is substantially zero at the left end where C_{16} is connected. In the same way, the RF signal, traveling along R_1 from left to right, is filtered out of the circuit by condensers C_3 and C_{16}.

The audio signal is now fed to the first audio amplifier by resistance-capacity coupling consisting of C_{24} and R_{11}. Note that the instantaneous AF signal voltage is maximum in Fig. 2 at the top end of grid resistor R_{11}, diminishing towards zero at ground as denoted by the green dashes. The AF signal across R_{11} swings above and below ground potential equal amounts.

You will note in Fig. 2 that part of the input circuit to the oscillator input grid is also blue—see R_3 and C_7. The reason for this is that practically the same condition exists as in the AVC circuit—that is, an automatic bias is provided for the input grid (No. 1) across R_3. The RF voltage that it develops is half-wave rectified between the cathode and the input grid and is more negative than ground. There is a point between the blue and yellow of the grid leak resistor R_3 where the potential is exactly zero. The voltage developed across R_3 varies from grid No. 1 to cathode —for example, from -20 volts to $+6$ volts. That is why R_3 is shown in two colors because part of it is above ground potential and part below. The effect of this, of course, is to apply an *average negative voltage* to the No. 1 grid as explained in a previous lesson for grid leak detection.

Such an action is possible in R_3 of Fig. 2 simply because there is a varying voltage in it—it being de-



Above are shown two types of electrolytic condensers made by Solar. These are known as the dry type and are often used in circuits where there is a heavy current to be filtered. The unit on the left contains three condensers, two of which are rated at 9 mfd. and one rated at 18 mfd. The working voltage is 450 volts. The unit on the right contains a single condenser rated at 1,000 mfd. with a working voltage of 12 volts. The latter condenser is, of course, used in low voltage circuits where heavy currents are to be filtered.

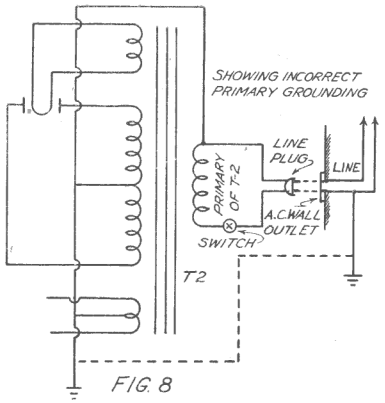


FIG. 8

veloped and controlled in the oscillator tuned circuit.

THE BROWN FILAMENT CIRCUIT

All of the filament circuits, with the exception of the rectifier type 5T4 tube, are shown in *brown* in Fig. 2. They are all in parallel with the centertap at the power transformer being grounded. This ground connection is to insure that the filaments will stay at ground potential as they would otherwise be insulated from ground, and their emission might form undesirable potentials in the filament circuit. The filaments, of course, in cathode tubes are not intended for emission, but the high temperature in the vacuum of a tube envelope may give rise to some emission. This ground connection to the center tap of the filament circuit carries surplus electrons to or from ground, and this brings about equalization of transient voltages.

Now if the filament winding in Fig. 2 supplies 6.3 volts, a potential of not more than .5×6.3 or 3.15 volts above or below, ground can be formed anywhere in the filament circuit. While one side of each filament is at a maximum of +3.15 volts, the other side at the same instant will be −3.15 volts. This is desirable to reduce the possibility of hum and disturbances resembling electrostatic interference resulting from an unbalance of filament voltages.

The primary winding of the power transpormer is shown in brown, also, as it carries 110 volts AC 60 cycle current. One side of the line is invariably grounded, holding it at constant potential—the other side, swinging in potential from a peak of 155 volts to −155 volts. The RMS value is, of course, .707×155 or 110 volts—the value at which the supply line is rated.

Neither side of the *primary* may be connected to the chassis or ground of the *receiver* because it is not known which way the power cord will be connected to the AC outlet. For example, if the *underground side* of the line happens to be connected to the *grounded side of the receiver,* the power line will be shorted. The correct and incorrect connections are shown, assuming the primary of transformer T2 is connected to the re-

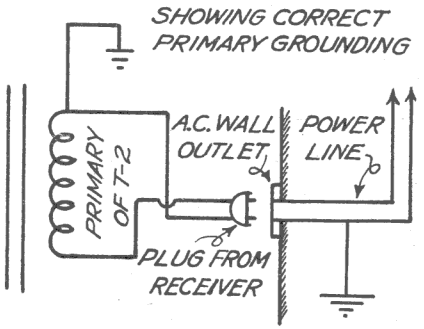


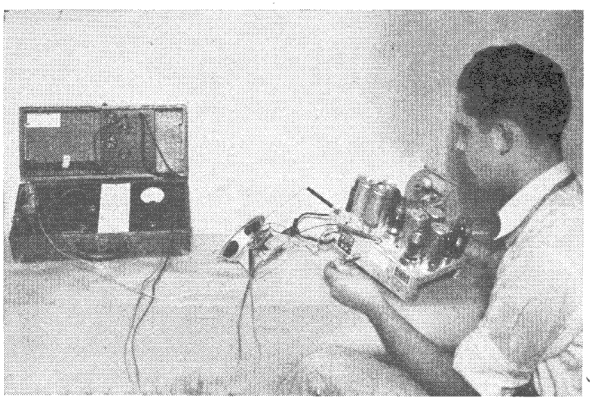
FIG. 9

ceiver chassis in Figs. 8 and 9. This shows clearly why the power transformer *primary cannot be grounded* to the chassis of the receiver. No polarity distinction is made in connecting to any electrical power outlet for AC.

THE RED RECTIFIER CIRCUIT

The filament winding of the rectifier tube is shown in red which indicates that the entire winding is at a high DC potential. This is from 300 to 450 volts RMS average for every AC receiver. Of course, a heavy AC current is necessary to operate the filament of the rectifier with a voltage across its terminals of 5 volts RMS for a 5T4 type tube. Principally because of condenser C_{29} the rectifier filament circuit in Fig. 2 remains fairly constant in potential as far as the filament is concerned. It will be observed that the AC plate voltage applied to the rectifier tube is in phase with that supplied to the filament—that is, both are in phase with the magnetic changes occurring in the transformer core. Now, as the AC plate voltage on one rectifier plate rises from zero in the positive direction, the other one, being equally negative, the filament voltage rises also from zero to 5×1.414 or, approximately, 7 volts peak value. Although they rise simultaneously, they do not add to one another because of C_{29}. In Fig. 10, curves show the AC plate voltage and also the actual voltage at the upper terminal of the 5T4 filament winding in Fig. 2. Note that this follows the true supply voltage almost exactly as though a cathode were used instead of a filament. The lower terminal of the filament circuit of opposite polarity becomes 7 (5×1.414) volts more negative than the top or upper terminal of the filament circuit. This, of course, refers to an instantaneous action—where one side of the filament is positive, the other must, of course, be negative.

The *peak* plate voltage applied to the plate of the rectifier tube is 530 (375×1.414) volts, the *peak* voltage of the upper terminal of the filament winding is 480 volts—there being, in effect, an AC 50 volt drop across the tube from plate to filament. The lower ter-



Here is a view duplicated in many service shops all over the country. This shows a test being made on a receiver chassis using a combination test instrument such as those made by Triplett.

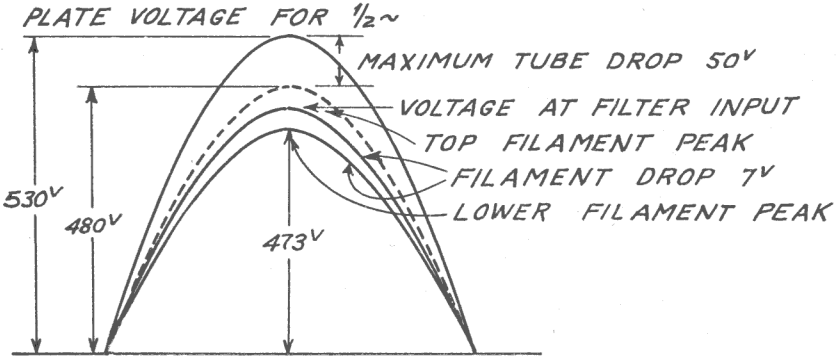


FIG. 10

minal of the filament winding in Fig. 2 will have a peak voltage of 530 −50 −7 or 473 volts. So, as the upper filament terminal voltage increases from 0 to 7 volts (AC) across its terminals, the potential of the entire filament winding is carried up to a peak of 480 volts with respect to the center tap on the high voltage winding of transformer T2. These details cannot easily be shown in colors. If the B+ of the filter input was connected to the lower filament terminal instead of the upper terminal, the DC output voltage of the rectifier would be the same. The upper filament terminal would increase in voltage up to 480 volts as indicated by the dotted line in Fig. 10. But, of course, this would not affect the ultimate voltage output of the rectifier system. *Figure 10, of course, shows conditions assuming no filter. Naturally, the filter tends to level off this uneven voltage output.*

THE RED PLATE CIRCUITS

All plate circuits and connections are shown in red in Fig. 2 because they carry high DC voltage. Starting with tube V1, the plate coil tuning condenser and B+ supply lead are all in red. The DC plate voltage is almost as high on one side of condenser C_{13} as on the other so both plates are shown in red. Condenser C_{12}, by-passing the plate circuit of tube V1 is also shown in red on the plate side as it is practically at the same DC potential as the plate of the tube. The plate of the tube is slightly lower in potential due to the DC resistance of L_7, but this small difference is not indicated by the red color.

Suppose a signal of 100 microvolts is being received and that the tube is capable of producing an IF signal in its plate circuit fifty times larger than the RF signal received. This is the *translation gain* of the tube, as you have learned. The signal voltage under these conditions will be 100×50 or 5000 microvolts or 5 millivolts peak (.005 volt).

The DC plate voltage will vary between 249.995 and 250.005 volts at the intermediate frequency. In other words, the voltage will be instantaneously rise .005 volt above the applied value and fall .005 volt below it. Assume this

value is amplified one hundred times by V2, giving a signal of 100 $\times$.005 or .5 volt at the control grid of V3. Its plate voltage (V2) being originally 250 volts also will vary but in this case at a rate between 259.5 and 250.5 volts due to the process of amplification. Now, if V3 also amplifies the signal one hundred times, its plate voltage will vary from 200 volts to a maximum of 300 volts at .5$\times$100=50 volts (250$-$50 and 250+50).

BYPASS CONDENSERS

Before going further, it will be well to investigate some very interesting points about by-pass condensers. As far as the voltage from plate to ground is concerned, the tuned circuit L_{12}-C_{21} of tube V3 is in series with the by-pass condenser C_{12}. Although the filter condenser C_{28} is in parallel with C_{12}, its effect in the circuit may be ignored. It should be mentioned here that C_{12} must be used because of the high impedance which would exist in the plate lead connecting C_{28} with L_7-C_{13}. For this reason, the condensers usually act individually and have separate distinct purposes although they seem to be in parallel, acting as a single large condenser. They are frequently connected through a long cable or, at least, a long lead. In reality, of course, such condensers as C_{11} and C_{12} present a short RF path to ground as explained in a previous lesson. The circuit of Fig. 11 shows the effective series connection of condenser C_{12}. This shows a total voltage E_1 having a peak value of 50 volts. Two impedances are present consisting of L_{12}-C_{21} and C_{12}. How will they divide the voltage E_1 into the two voltages E_2 and E_3? The impedance of L_{12}-C_{21} at an IF of 460 KC, to which it will be assumed it is tuned, is around 180,000 ohms. You have studied previously what contributes to this value and know that this value is quite reasonable. However, C_{12} is usually .1 mfd. or larger, and hence at 460 KC its reactance (rather than impedance) is equal to

$$= \frac{1}{6.28 \times f \times c}$$

$$= \frac{1}{6.28 \times 460{,}000 \times .1 \times 10^{-6}}$$

$$= \frac{1}{.289} = 3.64 \text{ ohms approximately}$$

Between these two impedances the 50 volt signal will obviously be divided in a ratio of 180,000 to 3.46. The ratio of the total voltage to that across C_{12} or E_3 is the same as the ratio of the total impedance of 180,003.46 ohms to 3.46 ohms. This may be expressed as:

$$\frac{E_3}{50} = \frac{3.46}{180{,}003.46} \text{ or}$$

$$E_3 = \frac{50 \times 3.46}{180{,}003.46}$$

$$= \frac{173}{180{,}003.46}$$

$$= .000961+$$

or approximately 961 microvolts.

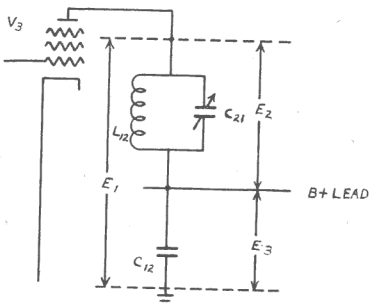


FIG. 11

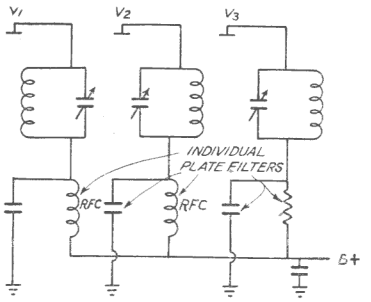


FIG. 12

This ripple voltage is impressed on the entire B+ terminal—thus affecting every connection made to it. At the plate of tube V1, the *RF signal voltage,* as you have learned, may be 5000 microvolts, or more than five times as great as 961 microvolts. Now, if this rises and falls in phase with that produced at the B+ terminal of V1, it will add to it ,giving regeneration. If the condenser value (C_{12}) is reduced to .02 mfd., a voltage drop of about 5000 microvolts will be produced across it, causing oscillation of the amplifier circuit. To prevent this effect, sometimes an RF choke or resistance filter is placed between the B+ terminal leading to each plate, as in Fig. 12. This is a method of avoiding any possibility of regeneration or oscillation in the plate circuit. The combination of R_{14}-C_{27} in the plate circuit of tube V4 in Fig. 2 is for just such a purpose. It prevents the audio signal voltage from creating a voltage drop across C_{12} which would be somewhat greater than 961 microvolts. Resistor R_{13} is lower than 180,000 ohms in the average case, and the signal voltage may be somewhat higher than 50 volts peak. This condition however, can not bring about oscillation or regeneration if a filter network similar to R_{14}-C_{27} is used.

No signal voltage is present at the B+ terminal of the push-pull stage because of the push-pull action which tends to maintain a constant voltage at the center tap connection. Thus, there cannot be any feedback from this source and no by-pass condenser is required at this point in the circuit.

THE SCREEN GRID VOLTAGE CIRCUIT

In practically the same manner as before you will see how the screen grid by-pass condenser (C_{11}) value is determined and—from what has been said about C_{12} it will be obvious how one screen voltage may feed into another screen grid circuit if not by-passed with a suitable condenser.

The last screen grid (V3) in Fig. 2 may be used as an example. Obviously, the precautions must be greater here. One series circuit of this tube consists of the screen grid to control grid capacity and condenser C_{11}. Obviously, with resistance R_5 included in the screen grid circuit there is present in effect, a rather *inefficient amplifier circuit* with R_5 acting as the load. This is composed of the control grid of V3, the screen grid with 100 volts impressed acting as an anode, the load R_5 and the other circuits plus R_6 loading the screen grid circuit to ground. It may be possible for the *gain* of this system to be as much as 3 *without the by-pass condenser* (C_{11}) under favorable conditions. Now with a signal of .5 volt on the grid of V3 there would be an AC output voltage of $.5 \times 3 = 1.5$ volts on the last screen grid were it not for C_{11}.

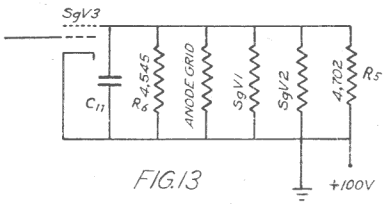


FIG. 13

Referring to Fig. 13 you will note that the total DC resistance from the screen grid circuit to ground is roughly around 4000 ohms. (The effect of all the parallel resistors). The screen grid of tube V3 *may have* an effective Rp, referring to it as a plate of 50,000 ohms, and its shunting effect would make it actually decrease a signal perhaps ten times in being transferred from control grid to plate.

When the by-pass condenser C_{11} is added to the circuit, its reactance will be 3.46 ohms at 460 KC (assuming a value of .1 mfd. for it). The effective Rp of the screen grid at 50,000 ohms is feeding a load of 3.46 ohms; thus the varying AC voltage on the screen grid is diminished some eight or ten thousand times—a desirable condition to prevent oscillation.

With a signal voltage of .5 volt on the control grid of V3, there will be, roughly, $\frac{.5}{4000}$ or .00012 volt or 120 microvolts on the screen grid. For a screen grid bypass condenser of .01 mfd. the reactance would be around 34.6 ohms at 460 KC. Thus, the signal voltage appearing on the screen grid would be cut down about one thousand times which is often sufficient. A value of .1 mfd. is better for C_{11} however, because there will be even less tendency to oscillate.

Concerning the possibility of screen grid feed-back causing regeneration, obviously the gain of this part of the tube acting as an auxiliary triode (cathode, control grid and screen as anode) must produre a gain greater than 1 before a voltage equal to the signal can be fed back to the control grid. The voltage variation at C_{11}, however, may possibly be transferred to other screen grids, but they cannot be effective in causing *circuit reactions* (oscillation or regeneration) unless they are larger than those already produced at these points.

AVC AND DETECTOR ACTION IN FIGURE 2

You have aready had considerabe study about the actions of detector and AVC circuits. However, you have not studied these circuits in equivalent form. The average student has difficulty with many detector and AVC circuits simply because of the many variations in them. These sometimes tax the ingenuity of the best radio men. However, all such circuits may be

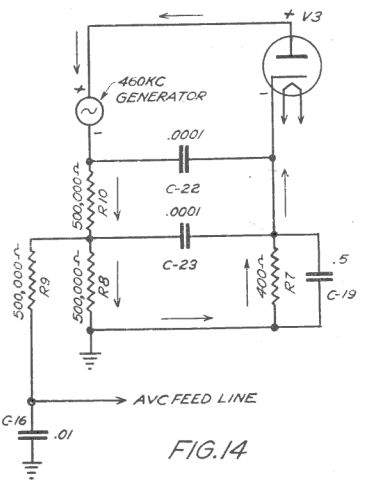
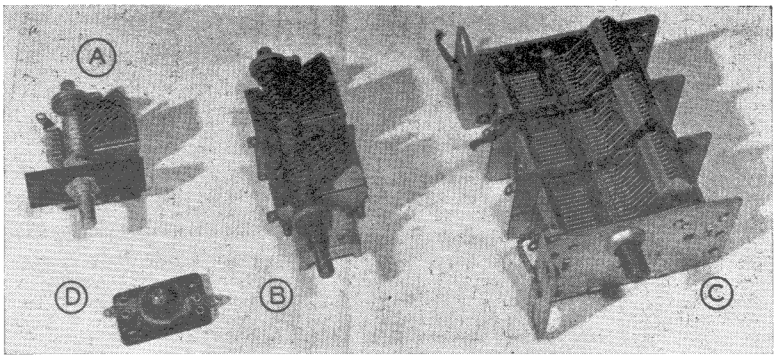


FIG. 14



Here are various forms of tuning condensers. In this view, A is a single gang unit, B shows a double gang and C three units ganged together. Condenser D is of the small trimmer or padder type.

reduced or made equivalent to a simplified form and when so treated they become easy to understand. Thus, the detector and AVC circuit of Fig. 2 will be treated in this manner. If you follow this process carefully step by step, you can apply this same treatment to any other detector-AVC circuit no matter how complicated, and its mode of operation will be made self-evident. Refer to Fig. 14 and note this corresponds electrically to the detector-AVC circuit of Fig. 2. *The tube symbol V3 in Fig. 14 only shows the diode function.* The two diode plates in Fig. 2 are connected together or common. Therefore, they may be shown as one element in Fig. 14 for half wave rectification. The tuned circuit of L_{11}-C_{20} feeds the diode plates and the cathode of tube V3 with an IF signal of 460 KC. Thus, it may be represented as a 460 KC generator as shown in Fig. 14. As usual, the direction of current flow is from cathode to plate as indicated by the arrows in Fig. 14. It is known that the generator furnishes a signal voltage equal to 460,000 cycles and that current can only flow through the diode tube in one direction. It would be impossible to trace the action of the tube 460,000 times in order to follow it through for one second of time. It is clear that what is true for one cycle must also be true for the other 459,999 cycles. Thus, if one cycle of events is traced through for the diode circuit, a complete picture of its entire action may be obtained. To eliminate as many items from the consideration as possible and to reduce the circuit to its simplest form, condenser C_{22}, C_{23} and C_{19} of Fig. 14 may be omitted from further consideration. It should be understood, however, that the purpose of C_{22} and C_{23} is to remove or filter the IF carrier wave, leaving the AF pulses to be distributed across R_{10} and R_8. Condenser C_{19} is, of course, for the purpose of holding the potential across R_7 constant so that the negative voltage on the diode plates and the control grid of tube V3 will not vary. With the foregoing assumptions made, the circuit of Fig. 14 may be further reduced to the equivalent of Fig. 15 and still re-

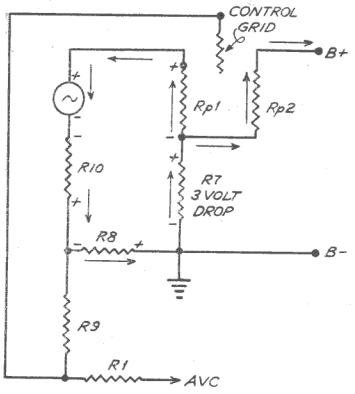
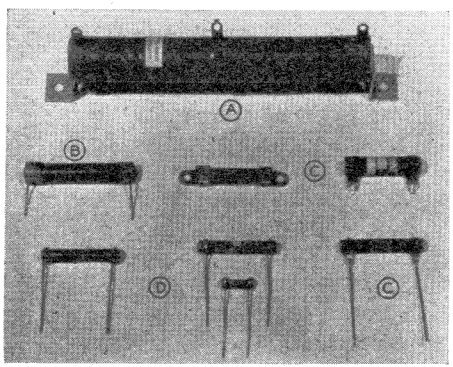


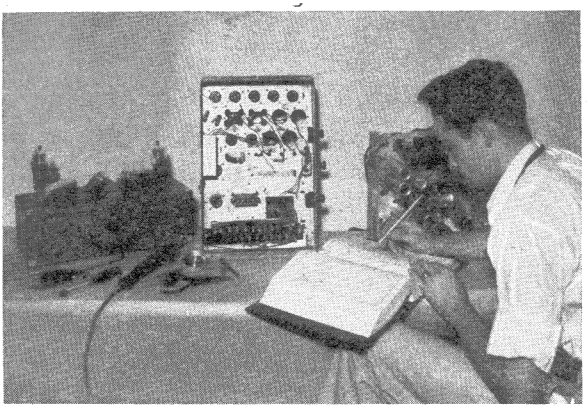
FIG. 15

main true. In this figure, the AC generator is the reference source —its positive terminal making the plate of the tube positive and its negative terminal making one end of R_{10} negative. You may assume direction of current flow with respect to the AC generator as beginning at the negative terminal of R_{10} and continuing on around the circuit through R_8, R_7, Rp1 and back to the positive terminal of the generator. The symbolic resistor Rp1 represents the internal resistance of the tube between diode plates and cathode. Likewise, Rp2 is a symbolic resistor representing the internal resistance of the pentode section of the tube between the pentode plate and cathode. It should be clear from this that the cathode is a common conducting element for the diode plates and also the pentode plate.

First consider the pentode section of the tube. Regardless of whether or not a signal is being received, there is a steady plate current flow through R_7 and Rp2 since the DC power supply is connected across these two elements in the circuit. This makes the negative or grounded end of R_7 3 volts negative and the other end of R_7 3 volts positive. As you have previously learned, a resistor connected as R_7 provides a voltage drop across its terminals which has the same polarity as indicated for R_7 in Fig. 15. The negative polarity of this voltage drop may be applied as a bias to any tube element common to the same cathode if it does not draw current —as, for instance, a control grid or diode plate. Thus, for a *no signal* condition in Fig. 14, the 3 volt drop across R_7 is applied to the diode plate element as a negative voltage—it being impressed between cathode and diode plate, diode negative, cathode positive. Do not let the + signs at the diode element in Figs. 14 and 15 confuse you on this point. These + signs are true only when a signal of greater than 3 volts is being delivered by the AC generator. With a signal of less than 3 volts, the diode element remains at a negative potential. This, you will remember, follows the principle of



This view shows several forms of resistors. Unit A is of the heavy duty wire wound type with a special cement coating to radiate heat and to hold the wire in place. B is a medium sized wire wound type—5 to 10 watts. D and C are, of course, 1 and 2 watt carbon types.



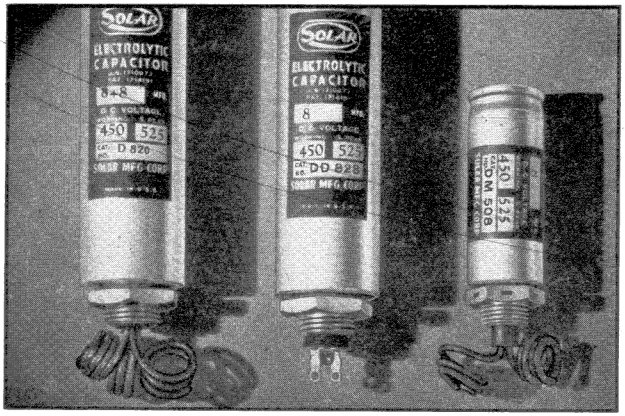
With so many thousands of receiving sets in use, it is impossible for service and repair men to remember all circuit details of them. This view shows the repair man looking up the circuit of a given receiver by means of circuit manuals which are available from most radio parts jobbers.

delayed AVC—detection being delayed until the signal reaches a value of greater than 3 volts—this being done to avoid noise at the lower signal strengths.

A received signal of 2.5 volts may be used to illustrate how the circuit works. With no signal being received, the diode plate is 3 volts negative with the cathode 3 volts positive; thus no current can flow through the tube for if this is to occur the plate must swing positive and the cathode negative. If the signal is 2.5 volts, the negative half cycle of it when applied to the diode plate will swing it to 3+2.5 or 5.5 volts negative with the cathode positive by the same amount. When the cycle reverses 2.5 volts positive will be applied to the diode plate, making it have a net *negative potential* of +3+(−2.5) or .5 volt with the cathode still positive by .5 volt. Note even though the signal cycle has reversed the tube will not rectify beause the plate is still negative with the cathode positive. This same principle would still apply for all signal voltage values up to 3 volts.

When the signal voltages exceed 3 volts, the tube will start to rectify and the polarity indications in Fig. 15 will hold true. Each resistor element in Fig. 15 has polarity indicated at each end with reference to the AC generator—assuming current flow starts at the negative terminal of the generator and continues through R_{10}, R_8, etc.

Assume the signal reaches a value of 23 volts. When this happens the net difference between the voltage drop across R_7 and the signal voltage is left to operate the diode detector. In this case, it is equal to 23 −3 or 20 volts. Thus, the diode plate is made 20 volts positive with the cathode 20 volts negative, and under this condition current will flow and the tube will rectify. All of this, of course, refers to the relative polarity of the diode plate and the cathode. It does not change the fact that the control grid of the tube remains at a constant negative potential with respect to the cathode of the tube for, in this case, a different circuit is involved entirely.



This view shows three types of electrolytic condensers which are usually mounted in a vertical position through a hole in the receiver or amplifier chassis. These are known as the screw base type—a nut on the underside of the chassis holding the condensers in place. Such condensers may be of either the wet or dry type. Courtesy of Solar.

To return to the condition of a 20 volt positive potential on the diode plate what voltage drops occur across the various resistor elements in Fig. 15? For the purpose of illustration, let Rp1 in Fig. 15 equal 50,000 ohms. This will give a total diode circuit resistance of 500,000 + 500,000 + 400 + 50,000 or 1,050,400 ohms with a consequent flow of $\frac{20}{1{,}050{,}400}$ or .000019 ampere if the internal resistance of the AC generator is neglected. For this condition, the voltage drop across R_{10} will equal 9.5 volts and the same amount will occur across R_8 because its resistance value is the same as R_{10}. Across R_7 the drop will be .0076 volt and across Rp1 it will be .95 volt for a total of 19.9576 volts—the odd value resulting from the fractional value of the current in the circuit.

Thus for a 23 volt received signal there will be an initial bias on the control grids of tubes V_1, V_2 and V_3 in Fig. 2 of 9.5+3 or 12.5 volts—the drop across R_7 plus that of R_8. In studying the foregoing action you should keep in mind that R_8 is also the volume control and that the AF signal is being taken off from it by virtue of condenser C_{24} in Fig. 2. Also you should keep in mind that Fig. 15 has omitted filter condensers which are necessary for full detector action. No voltage drops occur in resistors R_1 and R_9 in Figs. 2 and 15 for they do not conduct DC. Their main purpose is to filter and provide the correct time constant for the AVC in conjunction with condensers C_3 and C_{16}. You should now have a clear understanding of how the detector and AVC circuit functions in Fig. 2. Remember, however, Fig. 15 is simply symbolic of the circuit action. Such a circuit can be often used to simplify a more complex circuit and what you learn from such a simplification may be used as an index of what occurs from the varying conditions which are always imposed as a result of a varying signal.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1. How is it possible for the oscillator grid (G1) in Fig. 2 to be below ground potential when it is connected through R3 to the cathode of V1 which is positive?

No. 2. If there were no signal voltage present in the circuit of Fig. 2 what additional circuit parts would be indicated in black?

No. 3. Name the three resistors through which DC flows in Fig. 2 due to rectification.

No. 4. Why is it that one side of the power transformer in Fig. 2 cannot be grounded to the receiver chassis?

No. 5. Is the pentode section of V3 in Fig. 2 an amplifier or a detector?

No. 6. What determines the minimum bias voltage for the control grid of tube V1 in Fig. 2?

No. 7. Are the 80 rectifier tube plates in Fig. 2 always more positive than the filament or cathode of the tube?

No. 8. Name four factors which serve to determine the value of the screen grid voltage on all of the screen grids in Fig. 2.

No. 9. What is the purpose of condenser C12 in Figs. 2 and 11?

No. 10. What prevents the screen grids of the tubes in Fig. 2 from amplifying signals?